

## A Quantitative Analysis of Dental Attrition Rates in the Santa Barbara Channel Area

PHILLIP L. WALKER

*Department of Anthropology, University of California, Santa Barbara, California 93106*

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**ABSTRACT** The dentitions of individuals from archaeological sites located along the Santa Barbara Channel were analysed using quantitative methods which allow the accurate assessment of attrition rates. Comparisons of molar wear gradients indicate that attrition rates have decreased significantly through time in the Santa Barbara Channel area.

The patterning of wear on the dentitions of individuals recovered from archaeological excavations is a unique source of information concerning diet since it is the result of a direct interaction between the teeth of these individuals and the foods they consumed. From an archaeological standpoint, dietary information based on the analysis of dental attrition is of considerable value since it offers an independent check against reconstructions of prehistoric subsistence based on the analysis of floral, faunal and artifactual evidence.

Although it has been possible to discern correlations between diet and dental attrition on a gross level (e.g., Leigh, '25), the analytical techniques available have lacked the sensitivity necessary to measure small differences between closely related populations with access to slightly different food resources.

That attrition is a continuous process, correlated with age and body size as well as the abrasive quality of the diet, impedes the analysis of dental wear. Several techniques have been used in comparative studies of dental attrition to control for the age factor. When physiological age based on analysis of skeletal remains is used to divide populations into a series of age classes (Campbell, '39; Leigh, '28), interpopulation comparisons can then be limited to individuals of approximately the same age. The major drawback of this procedure is the fact that adequate skeletal material for the determination of physiological

age is often unavailable from archaeological proveniences.

Smith's ('72) alternative technique, based on the timing of molar eruption, does not require the estimation of skeletal age. Since the timing of dental eruption varies little between different human populations, the comparison of wear differentials between adjacent teeth in the molar series offers a measure of the amount of attrition during a relatively constant time interval. For example, the difference in the degree of attrition of the first and second molars is an index of the amount of attrition during the 6-year interval between eruption of the first and second molars.

Although the comparison of wear differentials between adjacent teeth appears to offer an accurate means of controlling for the variable of age, quantitative methods have rarely been used to measure the degree of attrition exhibited by individual teeth (LeBlanc and Black, '74). Most investigators use qualitative scales based on the arbitrary division of the wear on the occlusal surfaces of molars into a series of attrition classes (Leigh, '28; Goldstein, '48; Lysell, '58; Drennan, '29; Molnar, '71). Even with elaborate scales for scoring dental attrition the non-parametric statistical tests available for the analysis of these data lack the precision necessary to compare prehistoric ations with broadly similar diets.

The purpose of the present study is to present a quantitative analysis of dental attrition rates in prehistoric island and mainland

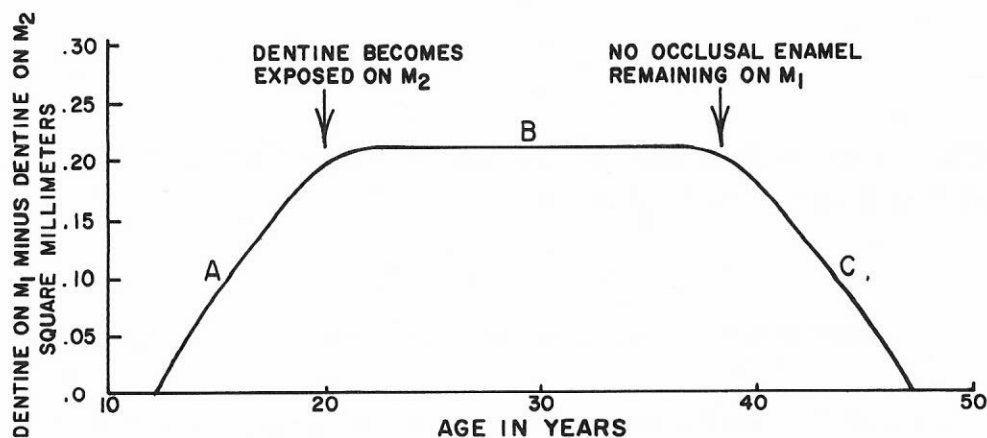


Fig. 1 A hypothetical distribution based on values derived from attrition rates in the prehistoric population of the Santa Barbara Channel area. Area of dentine exposed on the first mandibular molar minus the area of dentine exposed on the second mandibular molar is plotted against increasing skeletal age. A, area of the curve in which no dentine is exposed on the second molar; B, area of the curve in which proportionate increases in dentine exposures are produced on both molars; C, area of the curve in which difference values decrease since no occlusal enamel remains on the first molar.

populations living along the Santa Barbara Channel. By using a quantitative scale, inter-population differences were identified that would not be apparent using less precise qualitative systems of analysis.

#### MATERIALS AND METHODS

This study is based on the examination of the skeletal material in the collections of the Santa Barbara Museum of Natural History, Department of Anthropology of the University of California at Los Angeles, and the Department of Anthropology of the University of California at Santa Barbara. The dentitions of 64 individuals from two sites on Santa Rosa Island (S.B.M.N.H.-131.2b and S.B.M.N.H.-131.41a) and two sites from the mainland coast in the vicinity of Santa Barbara, California were analyzed. The site of Canada Verde (S.B.M.N.H.-131.41a) represents a relatively early occupation of Santa Rosa Island. Orr ('68) placed the site in his "Early Dune Dweller Period" dated between 7,500 and 6,800 B.P. (Glassow, '77). The Rincon cemetery (4-SBa-1) is one of the earliest mainland coastal sites in the Santa Barbara Channel area with skeletal material. According to Stickel ('68) it represents an occupation of the area during Rogers' ('29) "Hunting Period," which began about 3,000 B.C. (Harrison and Harrison, '66). A sample of black abalone (*Haliotis cracheroderi*) from the cemetery gave a radiocarbon date of  $3,685 \pm 80$  B.P.

(Stickel, '68). The Santa Rosa Island site of Skull Gulch (S.B.M.N.H.-131.2a) and the mainland site of Saqpilil (4-SBa-60) represent relatively late occupations of the Santa Barbara Channel area. Artifacts associated with burials from both sites indicate that these cemeteries are approximately contemporaneous, dating from the protohistoric Canaliño period. Samples of shell associated with burials from S.B.M.N.H.-131.2a produced dates of  $1,050 \pm 80$  B.P. and  $130 \pm 90$  B.P. (Orr, '68).

The samples from each site were selected to obtain approximately equal numbers of males and females. Individuals with pathological dental conditions potentially producing irregularities in occlusion or preferential use of specific areas of the dental arcade were excluded from the sample. The analysis of attrition was confined to the mandibular dentition since the collections studied contain few intact maxillae. Attrition was measured on the left side of the jaw except when a complete set of mandibular molars was present on the right side but not on the left.

Differences in the degree of attrition of adjacent molars can be considered a normally distributed constant reflecting the rate of dental attrition only when the sample analysed possesses the following attributes: (1) at least some dentine must be exposed on all molars; (2) at least some occlusal enamel must be present on all molars.

Young individuals lacking dentine exposure on all teeth are omitted since proportionate increases in the area of dentine exposed on adjacent molars can occur only when at least some dentine is exposed on both teeth under consideration (fig. 1:A). Old individuals completely lacking occlusal enamel cannot reasonably be included in the sample since as soon as the anterior tooth in a pair lacks occlusal enamel, difference values between the two teeth will begin to decrease because the area of dentine exposed in the distal tooth in the pair cannot be accompanied by a proportionate increase in the area of dentine exposed on the mesial tooth in the pair (fig. 1:C).

The area of occlusal dentine exposed on the mandibular molars of each specimen was measured from photographs taken with the camera's focal plane perpendicular to the surface of the tooth. A millimeter scale oriented parallel to and at the level of the occlusal surface was included in each photograph. Photographic negatives were projected at an enlargement of approximately  $70\times$  onto Vidalon drafting paper. The outline of the molar crown and all dentine exposures were measured with a compensating polar planimeter. To reduce the areas of the molar crown and dentine exposure to their actual dimensions, the length of the 5-mm interval on the enlarged millimeter scale was measured using vernier calipers. Replicability experiments indicate that areas of exposed occlusal dentine made using these procedures can be measured with an accuracy of  $\pm 0.003 \text{ mm}^2$ .

A summary measure of the wear differential of the entire molar row was produced by adding the differences between the areas of dentine exposed on  $M_1$  and  $M_2$ , and  $M_2$  and  $M_3$ . This produces a more sensitive measure of attrition rate than the comparison of individual molar pairs since it gives an estimate of the area of dentine exposed during a 12-year rather than a 6-year period. Use of wear on adjacent molars as an index of attrition rate requires the assumption that no interpopulation differences exist in the timing of molar eruption. The timing of  $M_1$  and  $M_2$  eruption varies relatively little, particularly when the groups compared are sampled from the same geographical area (Eveleth, '66; Eveleth and De Souza Freitas, '69). Timing of third molar eruption, in contrast, is much more variable. Use of differences in the area of dentine exposed on  $M_2$  and  $M_3$  is considered appropriate in the present study since t-tests indicate

that no significant differences ( $p > 0.05$ ) exist within each population studied in the amount of dentine exposed between the eruption of  $M_1$  and  $M_2$ , and  $M_2$  and  $M_3$  (i.e., dentine area  $M_1$ -dentine area  $M_2$  = dentine area  $M_2$ -dentine area  $M_3$ ). This consistency in the wear differentials between adjacent molars in each group indicates similar time intervals elapsed between the eruption of the mesial and distal tooth in each molar pair.

## RESULTS

### *Rates of dental attrition*

Significant differences between the groups studied in dentine wear differentials along the mandibular molar row appear to be correlated with the temporal relationships of the sites. The dentitions from early occupations of the Santa Barbara Channel Area (Canada Verde and Rincon) exhibit mean differences in dentine exposure for the entire molar row of  $0.415 \text{ mm}^2$  and  $0.436 \text{ mm}^2$  respectively (table 1). These values contrast significantly with the wear differentials for the protohistoric cemetery of Saqpilil ( $\bar{x} = 0.235 \text{ mm}^2$ ) on the mainland coast (table 1). The t-test indicates that rates of attrition at the late mainland site of Saqpilil and the late Santa Rosa Island site of Skull Gulch were not significantly different ( $t = 1.790$ , d.f. = 39,  $p > 0.05$ ).

### *Island-Mainland contrasts in body size*

Use of the wear differentials between groups as an index of the abrasive quality of the diet is based on the assumption that intergroup differences in body size do not exist. Since caloric intake is a direct function of body size, wear differentials could be produced between groups with identical diets but significantly different body size and food intake. Control for the possible influence of differences in body size was hindered since postcranial remains were unavailable for some of the individuals whose dentitions were used in the analysis of attrition rates. Analysis of variance indicates, however, that maximum femoral ( $F = 0.8016$ , d.f. = 27,  $p > 0.05$ ) and tibial ( $F = 0.9424$ , d.f. = 27,  $p > 0.05$ ) lengths do not differ significantly between the three cemeteries with adequate postcranial material (4-SBa-60, S.B.M.N.H.-131.2b and 131.41a). These similarities in longbone length indicate that the differences identified in attrition rates are probably not the result of intergroup differences in body size.

TABLE 1

Statistical comparisons of gradients in the mandibular row of populations from the Santa Barbara Channel area

Sites compared	Location	Sample size	Area of exposed dentine in mm <sup>2</sup> (dentine M <sub>1</sub> -dentine M <sub>2</sub> ) + (dentine M <sub>2</sub> -dentine M <sub>3</sub> )		Student's t (degrees of freedom)	P
			$\bar{X}$	S.D.		
Canada Verde	Santa Rosa Island	17	0.415	0.216	1.849	> 0.05
Skull Gulch	Santa Rosa Island	21	0.308	0.139	(36)	
Saqqilil	Mainland coast	20	0.235	0.121	1.790	> 0.05
Skull Gulch	Santa Rosa Island	21	0.308	0.139	(39)	
Saqqilil	Mainland coast	20	0.235	0.121	3.189	< 0.01
Canada Verde	Santa Rosa Island	17	0.415	0.216	(35)	
Rincon	Mainland coast	6	0.436	0.159	0.217	> 0.5
Canada Verde	Santa Rosa Island	17	0.415	0.216	(21)	
Rincon	Mainland coast	6	0.436	0.159	3.326	< 0.01
Saqqilil	Mainland coast	20	0.235	0.121	(24)	
Rincon	Mainland coast	6	0.436	0.159	1.931	> 0.05
Skull Gulch	Santa Rosa Island	21	0.308	0.139	(25)	

TABLE 2

Mandibular molar size of island and mainland populations from the South Santa Barbara Channel area

Site name and number	Location	Sample size	Mandibular molar areas in mm <sup>2</sup>						Summed mandibular molar areas	
			M <sub>1</sub>		M <sub>2</sub>		M <sub>3</sub>		$\bar{X}$	S.D.
			$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.		
S.B.M.N.H. 131.41a Canada Verde	Santa Rosa Island	17	11.457	1.91	11.026	1.70	9.870	1.64	32.35	4.79
4-SBa-1 Rincon	Mainland coast Santa Barbara county	6	9.919	0.53	9.720	0.92	8.982	0.82	28.62	1.51
S.B.M.N.H. 131.2b Skull Gulch	Santa Rosa Island	21	11.052	1.74	9.969	1.29	9.290	1.24	30.31	3.86
4-SBa-60 Saqqilil	Mainland coast Santa Barbara county	20	10.047	0.83	9.471	0.79	8.726	1.20	28.24	2.20

*Island-Mainland contrasts in molar size*

To test for correlations between molar area and attrition rates resulting from selection for large teeth in groups consuming diets producing rapid dental wear, the total mandibular molar area was calculated for one side of the jaw (table 2). Mean values for early ( $\bar{x}$  = 28.62 mm<sup>2</sup>) and late ( $\bar{x}$  = 28.24 mm<sup>2</sup>) mainland sites are virtually identical. The mean mandibular molar area for individuals from the early Santa Rosa Island site was 32.35 mm<sup>2</sup>, significantly larger than that for either of the mainland sites ( $t$  = 3.440, d.f. = 35,  $p$  < 0.005;  $t$  = 1.862, d.f. = 21,  $p$  < 0.05). Mean mandibular molar area of individuals from the late Santa Rosa Island site ( $\bar{x}$  = 30.31 mm<sup>2</sup>) is intermedi-

ate between the values for the mainland sites and the early Santa Rosa Island site.

## DISCUSSION

The striking floral, faunal and geographical contrasts within a relatively small area in the Santa Barbara Channel region provide data on ecological and cultural variables seldom available with archeological materials. Santa Rosa Island lacks many of the plant and animal species important in the subsistence of mainland populations. Only three species of terrestrial mammals are endemic to the island: the deer mouse (*Peromyscus maniculatus*), the island skunk (*Spilogale gracilis*), and the island fox (*Urocyon littoralis*). Oaks, an important source



of food for the inhabitants of the mainland, are relatively infrequent on Santa Rosa Island, occurring in small stands mainly confined to the steep slopes of major rivers. Archaeological evidence indicates that these biogeographical factors resulted in greater exploitation of marine resources on the Channel Islands than the mainland (Orr, '68; Glassow, '77; Rogers, '29).

At least during the protohistoric and historic periods trade between Island and mainland villages compensated for the disparity between the floral and faunal resources present on the islands and the mainland (King, '76). Although little direct evidence is available concerning how early significant amounts of plant and animal resources began to flow between the mainland and the Channel Islands, the development of the Chumash frameless plank canoe was probably critical to the development of an active system of inter-village exchange. The earliest archaeological evidence of plank canoes dates from about 500 A.D. (Travis Hudson, personal communication). This roughly coincides with the first appearance of certain classes of shell beads manufactured mainly on the Channel Islands which served as a medium of exchange throughout central and southern California (King, '76; M. Glassow, personal communication).

The relatively high rates of dental attrition on Santa Rosa Island at Canada Verde, a site dating from a period prior to the archaeological evidence for intensified island-mainland exchange of resources, suggest that, early in the prehistory of Santa Rosa Island, high rates of attrition resulted from a dietary adaptation with heavy emphasis on use of maritime resources. A major factor producing high attrition rates at Canada Verde was probably sand and grit associated with shellfish and other foods obtained from the littoral zone. Techniques for processing fish and sea mammal meat can also increase attrition. Although missionaries reported that the Chumash dried fish (Simpson, '62), they failed to specify what preparation techniques were employed. If they dried fish in the sand as described for the Tolowa of northern California (Gould, '76), high rates of attrition may have resulted. The similarity in attrition rate at the early mainland coastal cemetery at Rincon and the early Santa Rosa Island site at Canada Verde supports the contention that at

least some early mainland groups intensively exploited marine resources. Two less likely explanations might account for this similarity: (1) an active, but as yet unidentified, trade in food resources could have existed between the islands and mainland at a relatively early point in time, and (2) in the early mainland population, highly abrasive, attrition-producing plant material could have resulted in attrition rates similar to those on Santa Rosa Island. The low attrition rate at the protohistoric site of Saqqpilil indicates a dietary contrast between this group and the earlier inhabitants of the Santa Barbara Channel area. A variety of factors including intensified use of plant resources, changes in food processing, and local variations in the abrasive quality of the diet could account for this contrast. The archaeological evidence currently available is inadequate for the evaluation of these alternative possibilities.

#### *Mainland-Island contrasts in molar size*

The lack of archaeological evidence for early and extensive mainland-island exchange argues against trade in food resources as an explanation of mainland-island similarities in attrition rates. Independent evidence indicating less interaction earlier in time relates to mainland-island contrasts in molar size. Significant differences exist between the early island and mainland populations in total mandibular molar area (table 2). The similarity in tooth size between the two Santa Rosa Island groups and the contrast between these individuals and the mainlanders probably indicates relatively low levels of gene flow between island and mainland populations. The decrease in mainland-island molar size differences through time may be a product of increased levels of trade and gene flow during the protohistoric period. It is possible that the relatively large dental dimensions of the Santa Rosa Island population are the result of the founder effect or some other form of genetic drift. An equally plausible explanation is that the large molars of the Santa Rosa Island groups represent the adaptive response of a relatively small isolated population to a diet which produced high rates of attrition.

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